VIII. *On the Dissolution of Urinary Calculi in dilute Saline Fluids, at the Temperature of the Body, by the aid of Electricity.*

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In the year 1842 I published a statement of some of the attempts which had been made to dissolve urinary calculi. I did not then know that MM. Prevost and Dumas had made any researches on this subject. Some time afterwards I was told that they had used electricity, but I could not obtain the reference to their original paper; as no practical use was made of their experiments, I did not search for the record of them until after my own experiments were completed.

In 1845 I first devised the investigation which from circumstances I did not commence until 1848, when I made some experiments on the solution of uric acid calculi.

It appeared to me not unlikely that when a solution of nitrate of potassa was made to divide into potassa and nitric acid by means of electricity, if a piece of uric acid were held between the electrodes of the galvanic battery, then the potassa at the negative electrode and the nitric acid at the positive electrode would both act on the calculus.

Thus I expected that the fluid about the negative electrode would dissolve the uric acid, whilst the fluid about the positive electrode would decompose the uric acid. I considered that no great excess of acid or alkali would result, because after passing round the calculus I expected they would recombine, re-forming a neutral solution.

The battery used consisted of six pairs of Grove's plates. The action was continued about four hours. There was an effect produced on the uric acid at the negative pole, but no very decided result was obtained.

A second experiment gave so little encouragement that for the time the experiments were discontinued.

In the year 1851 I proposed again trying, under the same circumstances, the effect of nitre on uric acid, of sulphate of potash on oxalate of lime, and of lactate of soda on phosphatic calculi. I was unable to make any experiments until July 1852, when, through the kindness of Dr. Faraday, I was allowed to have the use of the batteries at the Royal Institution, and I had the valuable assistance of Mr. Anderson, by which the perfect action of these batteries was ensured.

Section I. *On the Solution of Uric Acid Calculi.*

After a few preliminary experiments, on the 3rd of July the first experiment was made; a piece of very compact uric acid calculus was put into a saturated solution of nitrate of potassa, between the electrodes of a battery consisting of ten pairs of Grove's plates. The fluid soon boiled; the action was continued between three and four hours, when the calculus was removed. It was found to be so deeply corroded and worn on both sides, that apparently nearly half the piece of uric acid calculus was gone (see Plate XIV. fig. (*a*) and (*b*). The solution of nitre was boiling the whole time. On the removal of the stone a few drops of the liquid were evaporated, and the evidence of uric acid was most distinct. The fluid was evaporated to dryness, treated with a drop or two of nitric acid, again evaporated to dryness, and exposed to the fumes of ammonia. The characteristic reaction of uric acid was obtained.

Hence, by this qualitative experiment, it was certain that at a boiling temperature uric acid between the electrodes could be dissolved in a saturated solution of nitre.

The question immediately arose, what effect would be produced when the solution of nitre was diluted, and when the temperature was about that of the human body.

Experiment 2.—The number of plates in the battery was reduced to one-half in order that the temperature might rise less rapidly. Only five pairs of plates were used. Ten cubic inches of saturated solution of nitre were mixed with thirty cubic inches of distilled water; the specific gravity of the mixture was 1029. The temperature was kept low by changing the solution in which the calculus and the electrodes were placed. Each glass contained nearly a pint of the solution of nitre. The piece of calculus weighed 48 grains, and it consisted of very compact uric acid.

The action began at 9^{h} 45^{m} A.M. and was continued to 1 P.M., the temperature of the solution being between 65° and 108°.

The action recommenced at 2^{h} 10^{m} P.M. and was continued to 5 P.M., the temperature being between 65° and 112°.

Total time 6^{h} 5^{m}.

The calculus was then removed and perfectly dried in a water-bath. It was not washed with water, so that some nitre probably remained on the calculus; when perfectly dry the uric acid weighed 37 grains. Hence, in six hours at least, 11 grains of uric acid were dissolved. The solution appeared to take place chiefly at the negative pole. The nitre solution became very slightly alkaline.

Experiment 3.—I was then anxious to know whether a larger piece of calculus and increased power of the battery would give me a satisfactory result; the piece of calculus, weighing 113 grains, consisted chiefly of uric acid, but the nucleus was oxalate of lime. The battery consisted of ten pairs of plates, and the electrodes and solution were the same as in the last experiment.

The action began at 10^h 10^m A.M. and was continued to 1 P.M., the temperature of the solution being between 67° and 104°.

The action was recommenced at 2^h 10^m P.M. and was continued to 5^h 30^m P.M., the temperature being between 70° and 108°.

Total time 6^h 10^m.

The calculus was then removed, dried in a water-bath, after which it weighed 99 grs., so that in six hours about 14 grains of uric acid were dissolved. The external surface of the calculus which had been in contact with the negative electrode was corroded, whilst the internal surface, which consisted of oxalate of lime and which had been in contact with the positive electrode, was apparently very slightly acted on. The solution of nitre was much discoloured, and on evaporating, even a few drops, uric acid was immediately detectable.

Experiment 4.—A whole uric acid calculus, weighing 111 grains, was put in a solution of nitre of specific gravity 1024·5. Ten pairs of plates were employed.

The action began at 9^h 35^m A.M. and was continued to 1^h 5^m P.M., the temperature of the solution being between 67° and 100°.

The action recommenced at 2^h 10^m P.M. and was continued until 5 P.M., the temperature being from 70° to 102°.

Total time 6^h 20^m.

The calculus when dried weighed 95 grains, so that in little more than six hours 16 grains of uric acid were dissolved. The solution took place almost entirely at the negative or alkaline electrode. The solution of nitre became slightly alkaline.

I was now desirous of trying whether the form of the electrodes at that part which was in contact with the calculus made any perceptible difference. Instead of a piece of thick platinum wire flattened, of the exact size and form of fig. 2, the wire was not flattened but only bent back. The breadth and length of the electrodes was nearly the same as in the previous experiments, but the surface in the former case was continuous, in the latter interrupted by a small space between the bent portions of the wire.

Experiment 5.—A whole calculus, consisting chiefly of uric acid, with a thin external coating of oxalate of lime with a little phosphate of lime, was employed. It weighed 57 grains. At first the lower electrode was made positive, and the upper electrode negative. The power of the battery and the strength of the solution were the same as in the last experiment.

The action began at 9^h 30^m A.M. and was continued to 1 P.M., the temperature of the solution being between 64° and 110°.

The action recommenced at 2 P.M., the electrodes were then reversed, the negative being below, and the action was continued to 5 P.M.; the temperature was from 70° to 120°.

Total time 6^h 45^m.

When dry the stone weighed 45 grains, so that the loss was 12 grains. Very little

action was apparent on the calculus until the alkali was evolved from below. At five o'clock a voltameter interposed in the circuit showed that 2 cubic inches of mixed gases were produced in three minutes, but at this time the action of the battery was going down.

No deduction could be made as to the influence of the different forms of the electrodes.

Being anxious to know whether increased power of the battery and a better arrangement for keeping the temperature about that of the human body would be attended with advantage, another uric acid calculus was taken. It was very flat, and had been divided. The half used weighed $107\frac{1}{2}$ grains. The electrodes were those used in the first experiments. The portions not in contact with the calculus were covered with glass. The negative electrode was on the external surface of the stone, and was below. The solution consisted of the same strength of nitre as before, but to three pints of the solution eight ounces of urine were added; this being taken as the largest quantity likely to be secreted during the time that the experiment was likely to be continued in the human body. The battery consisted of twenty pairs of GROVE'S plates. By means of a siphon leading from the vessel in which the calculus was placed, and by means of a reservoir with a stopcock, a continuous current of the solution was allowed to flow around the stone; thus the temperature could be most easily regulated.

Experiment 6.—The action began at $9^{h}\ 28^{m}$ A.M., the temperature of the solution then being 64°.

At $9^{h}\ 55^{m}$ A.M., the voltameter showed that 1 cubic inch of mixed gases was evolved in thirty-five seconds.

The action was stopped at $12^{h}\ 45^{m}$.

Total time $3^{h}\ 17^{m}$.

The calculus when dry weighed 80 grains, so that the loss was $27\frac{1}{2}$ grains in three hours and a quarter. There was a deep red stain on the calculus when it was removed from the solution; this increased on drying, but it was more marked at the negative than at the positive electrode. The calculus was partially cut in halves. (See fig. 3.) On the negative electrode there was a deposit, which, when scraped off and examined, proved to be earthy phosphate, probably a deposit from the urine. The calculus itself on the surface, near the negative electrode, was made white from a slight deposit of earthy phosphate.

The current of the solution of nitre was continuous throughout, and the temperature was kept between 90° and 106°; when the action was stopped, the fluid was still slightly acid from the urine which was originally added.

No other experiments were made with uric acid calculi, so that no deductions have to be made for unsuccessful experiments.

The results may be thus arranged :—

Exp. 1 lasted 4^h	in saturated solution of nitre,	temp. 212°	with 10 pairs.	Half dissolved.
Exp. 2 lasted 6^h 5^m,	$\frac{1}{4}$ nitre, $\frac{3}{4}$ water,	average 109°	with 5 pairs,	11 grs. dissolved.
Exp. 3 lasted 6^h 10^m,	$\frac{1}{4}$ nitre, $\frac{3}{4}$ water,	average 101°	with 10 pairs,	14 grs. dissolved.
Exp. 4 lasted 6^h 20^m,	$\frac{1}{4}$ nitre, $\frac{3}{4}$ water,	average 100°	with 10 pairs,	16 grs. dissolved.
Exp. 5 lasted 6^h 45^m,	$\frac{1}{4}$ nitre, $\frac{3}{4}$ water,	average 106°	with 10 pairs,	12 grs. dissolved.
Exp. 6 lasted 3^h 17^m,	$\frac{1}{4}$ nitre, $\frac{3}{4}$ water,	average 98°	with 20 pairs,	$27\frac{1}{2}$ grs. dissolved.

So that uric acid calculi can be dissolved in a moderately dilute solution of nitrate of potassa at the temperature of the human body, by the aid of electricity, at the rate of from two to nine grains an hour.

SECTION II. *On the Solution of Oxalate of Lime Calculi.*

My original conjecture was, that sulphate of soda would prove the best solvent of oxalate of lime. Having however obtained so good an action on uric acid by a solution of nitre, I determined first to see what the effect of the same solution would be on oxalate of lime.

Experiment 1.—Half a small oxalate of lime calculus, weighing 42·5 grains, was taken. The battery consisted of only five pair of GROVE's plates.

The solution of nitre was of the specific gravity 1028.

The action began at 9^h 25^m A.M., the temperature of the solution then was 65°.

The action was stopped at 4^h 35^m P.M., the temperature never rose above 90°.

Total time 7^h 10^m.

The calculus was then removed and perfectly dried; it then weighed 42 grains, so that in upwards of seven hours only half a grain was dissolved.

Experiment 2.—The same calculus, weighing 42 grains, was again placed in the same solution. The strength of the battery was doubled, being ten pairs.

The action began at 9^h 35^m A.M. and was continued to 1^h 15^m P.M., the temperature of the solution being between 70° and 115°.

The action recommenced at 2^h 30^m P.M. and continued to 5^h 50^m P.M., the temperature being between 75° and 104°.

Total time 7^h.

For the last two hours there was a great diminution in the power of the battery. The calculus when dry weighed 40 grains, so that in seven hours only 2 grains had been dissolved. It appeared that the divided surface was the one attacked; to this the positive electrode had been applied.

Experiment 3.—As the nitre solution had so little action, I proceeded to try the effect of a solution of sulphate of soda.

A solution of sulphate of soda was made, having the specific gravity 1034. The battery was of the same strength as in the previous experiment, and the same calculus was used, so that the comparative action of the solution of nitre and the solution

of sulphate of soda might be determined. The weight of the calculus then was 40 grains.

The action commenced at 9^h 10^m A.M. and was continued to 1 P.M., the temperature of the solution being between 64° and 104°.

The action recommenced at 2^h 5^m P.M. and was continued to 4^h 30^m P.M., the temperature being between 70° and 102°.

Total time 6^h 15^m.

The battery was in good condition throughout the day. When the calculus was dry it weighed 38 grains, so that in six hours and a quarter only 2 grains had been dissolved.

Comparing this with the previous experiment, there is no advantage in using the sulphate of soda instead of the nitrate of potash.

I proceeded to try whether a solution of chloride of sodium would be more efficacious than the sulphate of soda or nitrate of potash.

Experiment 4.—The calculus was taken which had already been used in the previous experiments, in order that the comparative result might be as conclusive as possible. The chloride of sodium was dissolved in undistilled water, and the specific gravity of the solution was 1053·5. The battery was of the same strength as before.

The action began at 9^h 30^m A.M. and was continued to 1 P.M., the temperature of the solution being between 68° and 108°.

The action recommenced at 2^h 15^m P.M. and was continued to 4^h 30^m P.M., the temperature being between 70° and 100°.

Total time 5^h 45^m.

During the whole action much chlorine gas was evolved. The stone was perfectly bleached in places. When dry it weighed 37 grains. In five hours and three quarters only 1 grain was dissolved; thus it was evident that a solution of common salt was inferior to a solution of Glauber-salt or of nitre. In consequence of these experiments, it appeared most desirable to try whether the solution of nitre could be made still more active, either by increasing the strength of the battery, by adding other substances to the solution of nitre, or by increasing the strength of the solution of nitre. For determining these questions the following experiments were made.

Experiment 5.—The battery was increased to double the number of plates; that is, to twenty pairs. The calculus was the same as before, and the solution of nitre had the specific gravity 1026.

The action began at 9^h 35 A.M. and was continued to 1 P.M., the temperature of the solution being between 67° and 130°.

The action recommenced at 2 P.M. and was continued to 4^h 45^m P.M., the temperature being between 70° and 100°.

Total time 6^h 10^m.

The action of the battery diminished at one o'clock, so that the full action was only 3^h 25^m.

The calculus when dry weighed 32 grains, so that the loss was 6 grains in 6^h 10^m. The solution was chiefly on the cut surface of the calculus, which was in contact with the positive electrode.

Thus it appeared that by increasing the intensity of the battery the solution of nitre acted more energetically. The calculus however was a very small one; it originally weighed $42\frac{1}{2}$ grains only. One quarter of this however was dissolved.

Experiment 6.—The addition of other substances to the nitre solution was then tried; and first, phosphate of soda was employed. To each pint of the nitre solution two ounces of a saturated solution of phosphate of soda were added. A divided oxalate of lime calculus was taken which weighed 173 grains. The battery consisted of twenty pairs of plates.

The action commenced at 9^h 30^m A.M. and was continued to 12^h 49^m A.M., the temperature of the solution being between 66° and 110°.

The total time was 3^h 19^m.

The calculus when dry weighed 172 grains, so that in 3^h 19^m the loss was only 1 grain.

The calculus was exceedingly compact. There was no action whatever apparent at the negative or alkaline electrode which was on the upper and cut surface; the solution was of course alkaline throughout the whole time. The battery was in excellent action.

Experiment 7.—Two ounces of a strong solution of bichromate of potash were then added to each pint of the nitre solution. The same calculus was taken; it weighed 172 grains. Twenty pair of plates were again used.

The action began at 9^h 30^m A.M. and was continued to 12^h 45^m A.M., the temperature being between 65° and 120°.

The total time was 3^h 15^m.

When the calculus was dry it weighed 170 grains, so that the loss in three hours and a quarter was only 2 grains. Apparently this was taken from the cut surface of the calculus. The external surface, which was exceedingly hard, was not attacked, though it was in contact with the positive electrode. Finding thus no success I returned again to the nitre solution.

Experiment 8.—The solution of nitre was taken of double the strength of that which had previously been used, that is, one-half saturated solution and one-half distilled water. I was desirous of knowing whether the oxalate of lime would be more soluble in this than in a weaker solution; the battery and the calculus were the same as before. The calculus weighed 170 grains.

The action began at 9^h 30^m A.M. and was continued to 12^h 47^m A.M.; the temperature of the solution was between 64° and 110°.

Total time was 3^h 17^m.

When dry the calculus weighed $167\frac{1}{2}$ grains, so that the total loss in three hours and seventeen minutes was only $2\frac{1}{2}$ grains. There was very slight action on the

external surface of the stone which was in contact with the positive electrode. The cut surface around the nucleus appeared most acted on. The very frequent changes of the solution consequent on the resistance being lessened, led to the adoption of a continuous stream of solution.

Experiment 9.—It appeared from the last experiment, that by doubling the strength of the solution no corresponding increase in the action on the calculus occurred. To be still further convinced, the same calculus with the same battery was taken, and a solution was used of only half the strength of the previous one; that is, it was one-fourth saturated solution of nitre and three-fourths water, by means of a small tube siphon which carried off an ounce of fluid in twenty seconds, and a vessel with a stopcock which supplied fresh fluid. The temperature of the solution in which the calculus was kept remained about 92°, never rising higher than 96°.

The action began at 10 A.M., the temperature then was 64°.

The action was stopped at 12^{h} 50^{m} A.M., the temperature then was 92°.

Total time 2^{h} 50^{m}.

The calculus when dry weighed 165 grains, so that in two hours and fifty minutes of continuous action $2\frac{1}{2}$ grains only were dissolved. By comparing this experiment with the previous one, it is so far certain, that, by increasing the strength of the solution of nitre, no more action on the calculus was obtained. The next question was whether, by increasing the strength of the battery, the solution of the oxalate of lime would more rapidly take place.

Experiment 10.—The same calculus was used as before; it weighed now 165 grains. The solution of nitre was the same strength as in the last experiment. The battery was increased to forty pairs of GROVE's plates. The temperature was kept down by about six pints of nitre solution, and as the liquid passed out of the decomposing glass it was cooled by ice, and then returned to the reservoir. The temperature was thus kept throughout the whole experiment from rising above 102°; one ounce ran through in five seconds.

The action began at 9^{h} 25^{m} A.M., the temperature then was 66°.

The action began at 9^{h} 47^{m} A.M. A voltameter placed in the circuit showed that 1 cubic inch of mixed gases was evolved in twenty seconds.

The action was stopped at 12^{h} 25^{m} A.M., the temperature throughout was between 98° and 102°.

The total time 3^{h}.

The calculus when dried weighed 160 grains, so that the total loss in three hours was only 5 grains. There were very slight marks of action on the external surface. The hardness of this surface was between that of fluor and calc spar; Mr. TENNANT placed it for me at 3·5.

The current was continuous for three hours; the battery was in perfect order, though diminishing in action towards the end of the experiment.

The result of these experiments with oxalate of lime may be thus arranged:—

	Average temp.	Pairs of plates.	Grs. dissolved.
Exp. 1 lasted 7h 10m, in solution $\frac{1}{4}$ nitre, $\frac{3}{4}$ water . . .	90°	5	$\frac{1}{2}$
Exp. 2 lasted 7 10, in solution $\frac{1}{4}$ nitre, $\frac{3}{4}$ water . . .	104	10	2
Exp. 3 lasted 6 15, in sulphate of soda	101	10	2
Exp. 4 lasted 5 45, in common salt	102	10	1
Exp. 5 lasted 6 10, in nitre $\frac{1}{4}$, water $\frac{3}{4}$	108	20	6
Exp. 6 lasted 3 19, in nitre $\frac{1}{4}$ with phosphate of soda .	110	20	1
Exp. 7 lasted 3 15, in nitre $\frac{1}{4}$ with bichrom. of potassa	111	20	2
Exp. 8 lasted 3 17, in nitre $\frac{1}{2}$, water $\frac{3}{4}$	110	20	$2\frac{1}{2}$
Exp. 9 lasted 2 50, in nitre $\frac{1}{4}$, water $\frac{3}{4}$	92	20	$2\frac{1}{2}$
Exp. 10 lasted 3, in nitre $\frac{1}{4}$, water $\frac{3}{4}$	100	40	5

Hence oxalate of lime calculi can be only very slowly dissolved in the solution of nitrate of potassa, which acts most energetically on uric acid calculi. The solution of the oxalate of lime is from $\frac{1}{2}$ a grain to 2 grains nearly an hour, so that the action is certainly four times as slow as in the case of uric acid calculi.

Such being the result when the calculus consisted of oxalate of lime only, it appeared desirable to determine what would be the effect when the calculus consisted of oxalate of lime with uric acid, or of oxalate of lime with the earthy phosphates.

Experiment 11.—Half an oxalate of lime calculus, which contained uric acid also on the external surface, weighed 258 grains. The solution of nitre, consisting of one-fourth nitre and three-fourths distilled water, with twenty pairs of plates, was employed.

The action began at 9^h 35^m A.M. and was continued to 1 P.M.; the temperature of the solution was between 64° and 120°.

Total time 3^h 25^m.

When dry the calculus weighed 254 grains, so that in three hours twenty-five minutes the loss was 4 grains. There was very little action on the calculus at the positive or acid electrode. The negative electrode was in contact with the external surface, and there the action had taken place.

Experiment 12.—The experiment with the same stone was repeated with the same solution and the same strength of battery. The solution was changed thirty-three times; the temperature was 110°; the time of action was three hours twenty-three minutes, in which the calculus lost 5 grains. There was very little action at the positive electrode, but very distinct at the negative electrode, which was on the upper and external surface.

Experiment 13.—Another small half calculus, consisting of oxalate of lime and uric acid, weighing 64 grains, was submitted to the action of twenty pairs of plates, whilst in a continuous stream of nitre of the same strength as before.

The action began at 9^h 32^m A.M., the temperature throughout was from 90° to 98°, and was stopped at 12^h 48^m A.M.

The total time 3^h 16^m.

When dry the stone weighed 60 grains, so that in three hours and a quarter 4 grains were dissolved.

The loss was chiefly on the cut surface, which was in contact with the negative or alkaline electrode. The surface was not regularly attacked, but some ridges were left, one very distinct, consisting of oxalate of lime. The external surface was below, and the acid appeared to have little or no effect on it.

It seemed from these experiments that uric acid and oxalate of lime together were more easily dissolved than oxalate of lime alone.

To determine whether oxalate of lime with the earthy phosphates was more soluble than oxalate of lime alone, the following experiments were made.

Experiment 14.—A whole calculus, consisting externally of oxalate of lime with phosphate of lime, weighing 186 grains, was acted on by twenty pairs of plates in the solution of nitre of the same strength as before.

The action began at 9^{h} 30^{m} A.M. and was continued to 1 P.M., the temperature of the solution being between 68° and 120°.

The action recommenced at 2^{h} 5^{m} P.M. and was continued to 3^{h} 35^{m} P.M., the temperature being between 70° and 100°.

The total time was 5^{h}. The last hour there was very little action of the battery.

The calculus when dry weighed 159 grains, so that in five hours 27 grains were dissolved; the result in this experiment was so much beyond my expectation that the same calculus was again submitted to the same reagents.

Experiment 15.—One grain having been removed for analysis the calculus weighed 158 grains.

The action began at 9^{h} 40^{m} A.M. and was continued to 12^{h} 45^{m} A.M., the temperature being between 65° and 130°.

The total time was 3^{h} 5^{m}.

When the calculus was dry it weighed $143\frac{1}{2}$ grains, so that in three hours and five minutes the calculus lost $14\frac{1}{2}$ grains.

The result of these experiments with oxalate of lime and uric acid, and with oxalate of lime and phosphates, may be thus arranged:—

	Average temp.	Pairs of plates.	Grs. dissolved.
Exp. 11 lasted 3^{h} 25^{m}, in solution of nitre $\frac{1}{4}$, water $\frac{3}{4}$.	109°	20	4
Exp. 12 lasted 3 23, in solution of nitre $\frac{1}{4}$, water $\frac{3}{4}$.	110	20	5
Exp. 13 lasted 3 16, in solution of nitre $\frac{1}{4}$, water $\frac{3}{4}$.	94	20	4
Exp. 14 lasted 5, in solution of nitre $\frac{1}{4}$, water $\frac{3}{4}$.	103	20	27
Exp. 15 lasted 3 5, in solution of nitre $\frac{1}{4}$, water $\frac{3}{4}$.	113	20	$14\frac{1}{2}$

Hence the oxalate and urate together can be slowly dissolved in the nitre solution, whilst the oxalate and phosphate together are very rapidly dissolved, namely, at the rate of from $4\frac{1}{2}$ to $5\frac{1}{2}$ grains an hour.

It appears then from these experiments that calculi consisting of oxalates with phosphates are very easily dissolved in a dilute solution of nitre at the temperature of the body by the aid of electricity; but that calculi consisting of oxalates with urates

are dissolved with difficulty, whilst calculi of oxalate of lime alone are acted on very slowly.

Section III. *On the Solution of Phosphatic Calculi and of Carbonate of Lime.*

Having found the solution of nitre so efficacious in its action on uric acid, and as it was at least as good if not better than any other solution in its action on oxalate of lime, it was most desirable that it should be found efficacious in its action on phosphatic calculi.

Experiment 1.—A piece of very hard phosphate of lime calculus, weighing 64 grains, was put into the nitre solution (one-fourth saturated solution and three-fourths distilled water). A battery of ten pairs of plates was first tried.

The action began at 9^h 15^m A.M. and was continued until 1^h 30^m P.M., the temperature being between 68° and 106°.

The action recommenced at 2 P.M. and was continued until 5 P.M., the temperature being between 70° and 106°.

The total time was 7^h 15^m.

The calculus when dry weighed 49 grains. Hence in seven hours and a quarter 15 grains were dissolved. The solution took place chiefly at the part in contact with the positive electrode.

Experiment 2.—A divided fusible calculus, weighing 85 grains, was subjected to the action of a battery of twenty pair. The solution of nitre was the same as before, but to three pints of the solution eight ounces of urine were added, being the quantity, or more than the quantity which would be secreted during the time of the experiment.

The action began at 9^h 27^m A.M.; the temperature of the solution was 70°.

The action was stopped at 10^h 40^m A.M.; the temperature was kept between 90° and 102°.

The total time was 1^h 13^m.

The calculus when dry weighed only 54 grains, so that the loss in one hour and thirteen minutes was 31 grains. The current was continuous throughout.

When the stone had been some time in the liquid, it was taken out with the electrodes still in contact. It then appeared that the stone had imbibed sufficient water to allow of the action going on through the wet stone without any liquid surrounding it. Hence probably the very rapid action which took place.

The negative electrode was found to be coated with earthy phosphates. The solution remained feebly acid throughout.

The positive electrode was below in contact with the external surface of the calculus which was cut through. See fig. 4.

On the Solution of Carbonate of Lime.

Experiment 3.—A piece of marble, weighing 170 grains, was put into the solution of nitre of specific gravity 1026. A galvanic battery of ten pairs of plates was employed.

The action began at 9^h 30^m A.M. and was continued until 1 P.M., the temperature being between 66° and 106°.

The action recommenced at 2 P.M. and was continued until 4 P.M., the temperature being between 70° and 108°.

The total time was $5\frac{1}{2}^h$.

The piece of marble when dry weighed 142½ grains, so that in five and a half hours 27½ grains were dissolved. The solution became slightly alkaline; the marble was dissolved at the part in contact with the positive electrode. See fig. 5.

Experiment 4.—Another mass of marble, with the same battery, was tried in a solution of sulphate of soda, specific gravity about 1034.

The action began at 9^h 30^m A.M. and was continued until 1 P.M., the temperature being between 87° and 100°.

The action recommenced at 2 P.M. and was continued until 5 P.M., the temperature being between 100° and 106°.

The total time was $6\frac{1}{2}^h$.

When the marble was dry it weighed 156½ grains. Hence in six hours and a half only 4½ grains of marble were dissolved. See fig. 6.

Without doubt the difficult solubility of the sulphate of lime was the cause that hindered the solution of the marble.

The contrast between the solution of nitre and the solution of Glauber-salt is very remarkable; the former being seven and a quarter times more efficacious than the latter.

The result of these experiments on the earthy phosphates and carbonate of lime may be thus arranged:—

	Average temp.	Pairs of plates.	Grs. dissolved.
Exp. 1 lasted 7h 15m in nitre solution	102°	10	15
Exp. 2 lasted 1h 13m in nitre solution	96	20	31
Exp. 3 lasted 5h 30m in nitre solution	104	10	27½
Exp. 4 lasted 6h 30m in Glauber-salt	101	10	4½

Hence it is evident that calculi consisting of the earthy phosphates or of carbonate of lime can be most rapidly dissolved in a nearly neutral dilute solution of nitre, at the temperature of the human body, by the aid of the galvanic battery.

Conclusions.

Thus, then, by the aid of electricity, from 2 to 9 grains of uric acid calculi can be dissolved in an hour, whilst in the same time from 2 to 25 grains of phosphatic calculi can be dissolved in a neutral dilute solution of nitre at the temperature of the body. However, only from half a grain to 2 grains of oxalate of lime can be removed by the same means in the same time. Still, if the stone consists of oxalate with urate, from 1 to 2 grains may be dissolved in an hour; and if it consist of oxalate with phosphate, from 4½ to 5½ grains can be taken away in an hour.

Such at least are the results which can be obtained with calculi which have been long removed from the bladder and have been dried at 212°. The harder the calculi the greater the difficulty in dissolving them; and as previous to their removal from the bladder they are far less hard than they are after they have become dry, and as calculi which are wet may perhaps allow of the passage of the electricity through their substance, instead of only through the surrounding solution, there is good reason to expect that there will be less chemical difficulty in dissolving them in the bladder than out of it.

The skill which has been acquired in catching calculi in the bladder, the art of plating with platinum, the manufacture of vulcanized India rubber, will, with Mr. WEISS's help, I hope, enable me to state at some future time what can be done in the body as well as out of it. Looking back now from the results that have been obtained, it appears as if they might have been foreseen.

The uric acid and the phosphatic calculi are produced by the opposite states of over acidity and alkalescence occurring in the urine for a considerable time. By means of the galvanic battery acting on a saline solution, acid and alkali can be made to appear at any desired spot, in any quantity and for any time. Thus these opposite conditions may be produced on the surface of the stone at the spot, and only at the spot, where the action is wanted to correct the consequence of too much acidity or alkalescence; whilst around the place of action an almost neutral solution will remain in contact with the bladder without causing irritation.

I cannot conclude without stating what is due to MM. PREVOST and DUMAS. Their note is printed in the Annales de Chemie, vol. xxiii. p. 202, 1823, Sur l'Emploi de la Pile dans le traitment des Calculs de la Vessie*.

In this note the *mechanical action* of the mixed gases (evolved from the decomposition of water) on a fusible calculus is stated to have been 12 grains in 12 hours; twenty-five pairs of plates being used and recharged each hour.

The possibility of dissolving uric acid calculi is rejected, and no mention is made of calculi consisting of oxalate of lime.

In a postscript it is said that the addition of a "certain quantity" of nitre gave, with phosphatic calculi, a better result than when water alone was used.

M. DUMAS appears afterwards to have occupied himself with experiments on the possibility of employing currents of electricity within the bladder of living animals, and not with the determination of the *chemical action* of substances evolved by the galvanic battery on the surface of different kinds of calculi.

I am indebted to Dr. DU BOIS REYMOND for a reference to a paper, vol. i. p. 154, Oesterrichische Medicinischen Jahrbucher 1848, On the Effect of Galvanism on Urinary Calculi, by Dr. LUDWIG MELICHER of Vienna. He has employed the electric current for the electrolysis of the calculus itself, not for setting substances free which can act chemically upon it. He has made experiments on the living human body in two cases, it is said, with success.

* See also Dr. PARIS's Pharmacologia, vol. i. p. 231. ed. 6.

Appendix to a paper on the Solution of Urinary Calculi in dilute Neutral Solutions, by the aid of Electricity.

By HENRY BENCE JONES, *M.D., F.R.S., Physician to St. George's Hospital.*

Received December 18, 1852.

SINCE the original paper was communicated to the Royal Society, it has appeared to me desirable to try whether more dilute solutions of nitrate of potash would have sufficient effect, when the strength of the battery and all other circumstances were the same as in the previous experiments.

The solution of nitre was therefore made to contain only 10 grains of nitre to an ounce of water; it had a specific gravity of 1015. Two ounces of urine were added to three pints of the nitre solution.

A fusible calculus, weighing when dry 352 grains, was placed in this solution between the electrodes of twenty pairs of GROVE's plates.

The action commenced at $9^h\ 20^m$ A.M., the temperature being 50°.

The action was stopped at $12^h\ 45^m$ A.M., the temperature being 98°, so that the total time was $3^h\ 23^m$. The calculus when dry weighed 324 grains, so that the total loss was 67 grains. See fig. 7.

Hence a solution of nitre of one-half the strength of that previously used is sufficient when decomposed to dissolve a fusible calculus at the rate of 19 grains an hour.

In order to observe the effect of reducing the strength of the battery when a dilute solution of nitre was employed, another calculus, consisting externally of phosphates, was placed in a solution of nitre, specific gravity 1015, and this was decomposed by ten pairs of GROVE's plates.

The weight of the calculus when dry was 217 grains.

The action began at 9 A.M., the temperature then being 50°; at $12^h\ 45^m$ A.M. the action was stopped, the temperature being 98°.

The action was recommenced at 2 P.M., temperature 60°.

It was finally stopped at $4^h\ 45^m$ P.M., temperature 98°.

The total time was $6^h\ 30^m$. The solution of nitre did not require to be changed during the whole time, the temperature remaining constant. After being acted on, the calculus when dry weighed 197 grains, so that the total loss was 20 grains.

Hence in twice the time not one-third of the effect shown in the previous experiment was obtained, though this was chiefly owing to the diminished power of the battery, yet the greater hardness of the calculus used in this last experiment no doubt influenced the result.

I then proceeded to try the effect of the dilute solution of nitre on a uric acid calculus.

A uric acid calculus, weighing 403 grains, was placed in a solution of nitre, specific gravity 1015, which was decomposed by twenty pairs of GROVE's plates.

The action commenced at 8^h 56^m A.M., temperature being 50°. The action was stopped at 12^h 45^m A.M., temperature being 98°. The action recommenced at 2 P.M., temperature 52°. Finally stopped at 4^h 41^m P.M., temperature being 97°.

Hence the total time was 6^h 30^m. The calculus when dried weighed 381 grains, so that the total loss was 22 grains, or about $3\frac{1}{2}$ grains each hour. See fig. 8.

It appears then from this experiment that the effect on a uric acid calculus, when a dilute solution of nitre is employed, is less than one-half of the effect produced when a solution of nitre of double the strength is used.

From these experiments, it is evident that phosphatic and uric acid calculi can be dissolved in a very dilute solution of nitrate of potash, but the weaker the solution the longer the time required to obtain equal results.

Lastly, an experiment made on an undried phosphatic calculus, fresh from the bladder, showed that the action on the wet calculus was more rapid than when it was previously dried; but the nature of the experiment does not admit of a numerical statement of the result. See fig. 9. The electrodes in this experiment were much longer than those previously used.

The mechanical difficulties in making an instrument (litholyte) to be used in the body have not yet been completely overcome.

It is essentially requisite in such an instrument,—

First. That the insulation should be perfect, in order that the chemical action may be transferred to the surface of the stone.

Secondly. That no chemical action should be set up on the surface of the bladder or the urethra, whereby the mucous membrane might be injured.

Thirdly. It may be necessary that a double passage for the injection of the solution of nitre should exist, in order to keep down the temperature and to admit of the escape of the gas evolved in the bladder.

Already many instruments have been made for me by Mr. WEISS, yet hitherto a perfectly safe one has not enabled me to make experiments on the solution of calculi within the body.

Explanation of the Plate.

PLATE XIV.

Representing the exact size of the calculi and the extent of action.

Fig. 1 (*a*). Uric acid before it was acted on.
(*b*). The same after action.
Fig. 2. The electrodes of the exact size and shape used.
Fig. 3. Uric acid calculus acted on in the nitre solution.
Fig. 4. Phosphatic calculus in the same solution.
Fig. 5. Piece of marble in solution of nitre.
Fig. 6. Piece of marble in solution of Glauber-salt.
Fig. 7. Phosphatic calculus in a more dilute solution of nitre.
Fig. 8. Uric acid calculus in a more dilute solution of nitre.
Fig. 9. A calculus as moist as when taken from the bladder, acted upon in nitre with larger electrodes.

Fig. 9.

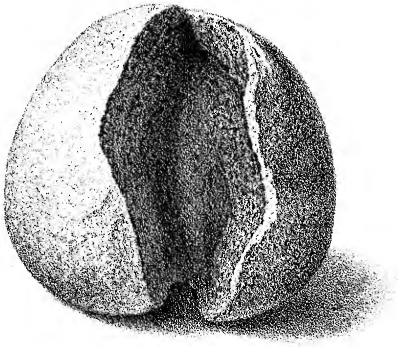


Fig. 6.

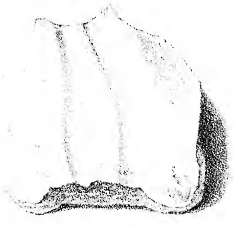


Fig. 1.ª

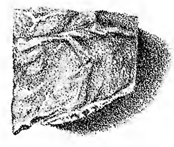


Fig. 8.

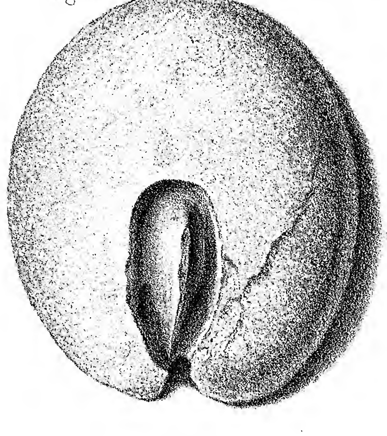


Fig. 5.

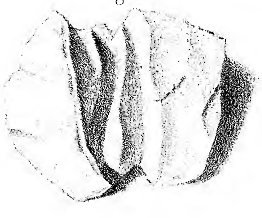


Fig. 1.ᵇ

Fig. 3.

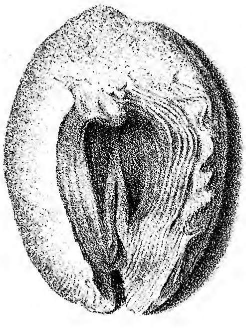


Fig. 4.

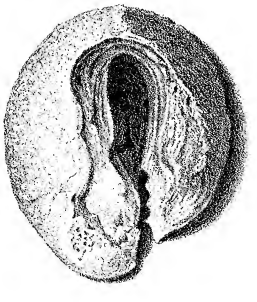


Fig. 7.

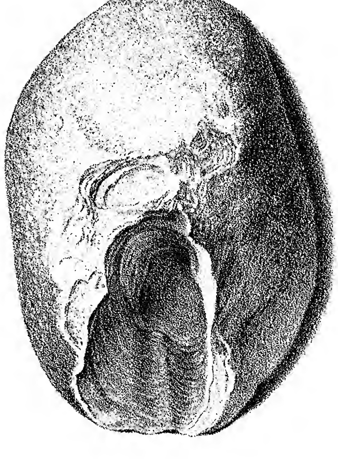
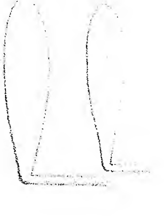


Fig. 2.



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